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Multilayer Optical Disc

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a multilayer optical disc having a plurality of data recording layers each of which is read with a light beam emitted thereto from the same side, and at least one of which is optically recordable.

2. Description of Related Art

Various types of recordable optical discs have been developed as means for recording large volumes of information. Different approaches have been used to achieve a high recording density, including reducing the track pitch, increasing the linear density by recording shorter marks, and land and groove recording for recording to both trench-like groove tracks and the land tracks between the groove tracks. While it has conventionally been possible to record and play only one recording layer from the same side of the disc (the side to which the laser is incident, also referred to herein as the laser incidence side), read-only discs with multiple recording layers enabling two data recording layers to be read from the same side of the disc have since been developed. Recordable multiple layer discs are expected to soon follow.

Sector management is needed to record and read data on a recordable multilayer optical disc. This is typically enabled during disc manufacture by forming guide grooves for tracking control and pits for recording sector address data. Sector address information identifying individual sectors must also be recorded to both land and groove tracks in order to record data to both land and groove tracks on a recordable multilayer optical disc.

Fig. 9 shows a conventional multilayer optical disc 91. This multilayer optical disc 91 has trench-shaped groove track 93 and land track 92 between the groove tracks. As shown in Fig. 10, address blocks 1001 and 1002 are recorded on groove track 93a, and address blocks 1003 and 1004 are recorded on land track 92a. A benefit of recording the address blocks staggered between adjacent land tracks and groove tracks in the track direction is that crosstalk is less likely when reproducing the address data.

SUMMARY OF THE INVENTION

1. Technical problem to be solved

Fig. 11 is a section view of a conventional recordable two-layer optical disc. Shown in Fig. 11 are transparent substrates 1101 and 1102 made of polycarbonate resin, for example; a first recording film 1103; semitransparent reflective film 1104 for passing or

reflecting light incident from substrate 1101; second recording film 1105; reflective film 1106 for reflecting a laser beam incident from substrate 1101; and adhesive 1107 with the ability to pass light used to bond substrate 1101 and substrate 1102.

When reproducing a signal recorded to the second recording film 1105, for example, from a disc configured as shown in Fig. 11, the read laser is partially reflected by the first recording film 1103 and collected on a photodetector. Likewise, when reproducing a signal recorded to the first recording film 1103, part of the laser beam passes the first recording film 1103 and is reflected by the second recording film 1105, passes again through the first recording film 1103, and is then incident to the photodetector. It will thus be apparent that when reproducing a signal recorded to either the first or the second recording film, playback is also affected by extraneous light from the layer not being read.

It is therefore important to minimize both the reflection of light from other layers and fluctuation in the reflection of light from other layers, in order to achieve a stable playback signal. Because of the need to assure sufficient signal amplitude in the playback signals from each recording layer, light reflections from other layers can be reduced a certain degree by optimizing the recording

film composition, but this provides little freedom of control over these reflections.

Fluctuation in light reflections from other layers varies greatly depending on how much of the laser spot incident to the other layer hits a data area and how much hits an address area. As shown in Fig. 10, a smooth mirror surface free of grooves and pits occupies a greater percentage of the address area 94 than the data area 95, thus reducing light diffraction and increasing reflection. This means that if when reproducing data from the second layer, for example, an address area occupies a large percentage of the laser spot incident to the first layer, an unwanted dc component will be superimposed on the amplitude of the signal from the second layer, and fluctuation is thus produced in the playback signal. This is shown in Fig. 12.

Fig. 12 shows recording marks 121 recorded to the second layer, light spots 122, 123, and 124 for reproducing the second layer, and light spots 125, 126, and 127 incident to the first layer when reproducing signals recorded to the second layer. Light spots 122 and 125, 123 and 126, and 124 and 127 are temporally coincident, and are corresponding pairs of light spots emitted to the first and second layers. The diameter of the laser beam incident to each layer is approximately 1 μm on the second layer

and approximately 60 μm on the first layer if the wavelength of the laser is 650 nm, the NA of the objective lens is 0.6, and the distance between layers is 40 μm.

Also shown in Fig. 12 are the envelope 129 of the playback signal for a signal recorded to the second layer of a two-layer disc thus comprised, and the envelope 128 of the playback signal of a signal recorded to a single-layer optical disc having recording characteristics equivalent to those of the second layer of the two-layer disc. That envelope 129 has a local deviation not present in envelope 128 will be apparent. This is because an address area occupies a large part of the area illuminated by the corresponding light spot 126 incident to the first layer in the area of light spot 123, and reflection from this mirror area is superimposed on the playback signal from the second layer.

Imposing such an unwanted dc component on the playback signal produces a local fluctuation in the envelope. When this fluctuation is great such as shown in areas 1210 and 1211, the playback signal cannot be correctly digitized. Conversely, if the operating frequency of the digitizing circuit generating the digital signal is increased in order to track sudden changes in the envelope, the digitizer will also track signals that should not be tracked because of defects and similar problems. Playback performance drops

as a result.

When a conventional addressing technique is thus used with a two-layer disc, the playback signal is incorrectly digitized where the envelope changes greatly, and the correct data cannot, therefore, be reproduced.

The present invention is directed to resolving this problem by providing a multilayer optical disc able to reproduce data correctly by not being affected by layers other than the playback layer.

2. Solution

A multilayer optical disc according to the present invention has plural data recording layers of which at least one is optically recordable, and to achieve the above object the diffraction efficiency of a light beam incident to the optically recordable data recording layer is within a specific range in the data recording layer when reading data from a data recording layer other than the optically recordable layer.

In a further multilayer optical disc according to the present invention having plural data recording layers of which at least one is optically recordable, the optically recordable layer has a data area and address areas for identifying a location in the data area, the address areas contain a pit and land sequence, and a groove or a pit and land sequence is disposed near each address block in the

address areas.

A further multilayer optical disc according to the present invention has two data recording layers each read by a light beam emitted thereto from the same side, a groove near the address blocks of the address areas in one recording layer, and pit and land sequences near the address blocks of the address areas in the other recording layer.

The address areas of a multilayer optical disc according to the present invention further record pit and land sequences, and have a groove or a pit and land sequence disposed in an area adjacent to the address areas in the radial direction. Alternatively, a groove or a pit and land sequence is disposed in an area adjacent to the address areas in the circumferential direction.

Further alternatively, the width of the groove or pit and land sequence adjacent to the address blocks decreases as the distance from the address area increases.

Other objects and attainments together with a fuller understanding of the invention will become apparent and appreciated by referring to the following description and claims taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional view of a two-layer optical disc according to a preferred embodiment of the invention;

Fig. 2 is a plan view of a two-layer optical disc according to a preferred embodiment of the invention;

Fig. 3 is an enlarged view of the address area in a preferred embodiment of the present invention;

Fig. 4 is used to describe a playback signal in a preferred embodiment of the present invention;

Fig. 5 is a sectional view of a two-layer optical disc according to a second embodiment of the invention;

Fig. 6 is a plan view of a two-layer optical disc according to a second embodiment of the invention;

Fig. 7 is an enlarged view of the address area in the second embodiment of the present invention;

Fig. 8 is used to describe a playback signal in the second embodiment of the present invention;

Fig. 9 is a plan view of a conventional two-layer optical disc;

Fig. 10 is an enlarged view of the address area in a conventional optical disc;

Fig. 11 is a section view of a two-layer optical disc according to the related art;

Fig. 12 is used to describe a playback signal in this example of the related art;

Fig. 13 is an enlarged view of the address area in

a preferred embodiment of the present invention;

Fig. 14 is an enlarged view of the address area in a preferred embodiment of the present invention;

Fig. 15 is an enlarged view of the address area in a preferred embodiment of the present invention;

Fig. 16 is an enlarged view of randomly located address areas in a preferred embodiment of the present invention;

Fig. 17 is an enlarged view of spirally located address areas in a preferred embodiment of the present invention;

Fig. 18 is an enlarged view of dispersely spirally located address areas in a preferred embodiment of the present invention;

Fig. 19 is an enlarged view of the address area shown in Fig. 17;

Fig. 20 (a) is an enlarged view of the address area shown in Fig. 18 when disposed diagonally, and Fig. 20 (b) is an enlarged view of the address area when disposed perpendicularly to the direction of light spot travel (radially to the disc);

Fig. 21 (a) is an enlarged view of the address area shown in Fig. 17 when disposed diagonally, and Fig. 21 (b) is an enlarged view of the address area when disposed perpendicularly to the direction of light spot travel

(radially to the disc);

Fig. 22 is an exploded view of a two-layer optical disc used in a recording apparatus according to the present invention;

Fig. 23 is a block diagram of a recording apparatus according to the present invention;

Fig. 24 (a) to (f) are used to describe a recording method according to the present invention;

Fig. 25 is a plan view of a two-layer optical disc used in a recording apparatus according to the present invention;

Fig. 26 describes recording to a two-layer optical disc used in a recording apparatus according to the present invention;

Fig. 27 (a) to (c) describe recording an optical disc by a recording apparatus of the related art; and

Fig. 28 shows the optical characteristics of a phase-change recording medium.

DESCRIPTION OF PREFERRED EMBODIMENTS

Preferred embodiments of the present invention are described below with reference to the accompanying figures.

Embodiment 1

Fig. 1 is a section view of a two-layer optical disc

according to a first embodiment of the present invention. As shown in Fig. 1, this two-layer optical disc has transparent substrates 101 and 102 typically made of polycarbonate resin, a first recording film 103, semitransparent reflective film 104 for passing or reflecting a laser beam incident from substrate 101; second recording film 105; reflective film 106 for reflecting a laser beam incident from substrate 101; and adhesive 107 with the ability to pass light used to bond substrate 101 and substrate 102.

Fig. 2 shows the sector structure of the two-layer optical disc shown in Fig. 1. As shown in Fig. 2, this two-layer optical disc 21 has a trench-like groove track 23 and a land track 22 disposed between adjacent groove tracks 23. Data is recorded to both groove tracks and land tracks. Each revolution of each track is divided into one or more address areas 24 and data areas 25. When one revolution of each track is divided into plural sectors, an address area 24 and data area 25 are provided for each sector. In this case each address area 24 is also referred to as a "sector address area." It will be noted that the groove tracks and land tracks can be formed as continuous spiral tracks.

Fig. 3 shows the address area 24 of the two-layer optical disc 21 in detail. An address area indicating the address of a particular sector is provided to each of the groove tracks 23a, 23b, 23c and land tracks 22a, 22b

shown in the figure. To indicate the address of groove track 23a, for example, two address blocks 31 and 32 each having a plurality of pit sequences are provided in address area 24. Two address blocks 33 and 34 each having a plurality of pit sequences is also provided for land track 22a. Dummy grooves 311, 312, 313, 314, 315 are also provided. Note that the address blocks 31, 32, 33, 34 are represented in the figure with a single open circle, but actually comprise a sequence of multiple consecutive prepits arrayed in the track direction. In addition, the dummy grooves 311, 312, 313, 314, 315 are represented with long horizontal rectangles in the figure, but in practice can comprise a sequence of multiple consecutive prepits arrayed in the track direction or a single long, narrow rectangular trench. If a single narrow long rectangular trench is used, the groove can be interrupted with mirror areas.

The dummy grooves are detected by detecting the dummy groove itself, or based on the distance between mirror areas before or after the dummy groove. The actual dummy grooves 311, 312, 313, 314, 315 can be detected by recording the dummy grooves as pit sequences that will not appear in the actual recorded data (such pit sequences including a single long rectangular groove), or by recording the dummy grooves as a pit sequence specifically

identifying the dummy grooves, so that the pit sequence detected from the dummy grooves can be distinguished from valid data recorded in the address blocks and data tracks. If the dummy grooves are detected based on the distance between mirror areas before or after the dummy grooves, a mirror area with a specific width is disposed either preceding or following each of the dummy grooves 311, 312, 313, 314, 315, and the dummy grooves are detected by detecting these mirror areas.

The address blocks for adjacent land tracks and groove tracks are staggered in the track direction, thereby reducing the likelihood of crosstalk occurring when reading address data. The dummy grooves 311, 312 are formed as rectangular trenches of substantially equal width, and thus produce no crosstalk.

Fig. 4 shows recording marks 41 recorded to the second recording layer, light spots 42, 43, 44 for reproducing data from the second recording layer, and light spots 45, 46, 47 incident to the first recording layer when reproducing signals recorded to the second recording layer. Light spots 42 and 45, 43 and 46, and 44 and 47 are temporally coincident pairs of light spots emitted to the first and second layers. The diameter of the laser beam incident to each layer is approximately 1 μm on the second layer and approximately 60 μm on the first layer if the wavelength

of the laser is 650 nm, the NA of the objective lens is 0.6, and the distance between layers is 40 μm.

Also shown in Fig. 4 are playback signal envelopes 48, 49, 410 where envelope 48 is the envelope of the playback signal of a signal recorded to a single-layer optical disc having recording characteristics equivalent to those of the second layer of the two-layer disc. Envelope 49 is the playback signal envelope when a signal recorded to the second recording layer of a conventional two-layer optical disc, that is, a two-layer optical disc that does not have dummy grooves, is reproduced. That envelope 49 has a local deviation not present in envelope 48 will be apparent. This is because when light spot 43 is emitted to read the second recording layer, an address area occupies part of the area illuminated by the corresponding light spot 46 incident to the first layer in the area of light spot 43, and reflection from the mirror part of the address area is superposed on the playback signal from the second layer. The playback signals cannot be correctly digitized in areas 411 and 412 of envelope 49.

Envelope 410, on the other hand, is the envelope for a playback signal reproduced from a signal recorded to the second recording layer of a two-layer optical disc having dummy grooves according to the present invention. Because of the dummy grooves in the address area of the

first layer, the mirror area is smaller and the unwanted dc components superimposed on the playback signal from the second layer are reduced. This reduces local fluctuation in the playback signal, enabling the playback signal to be correctly digitized, and thereby enabling the recorded data to be correctly reproduced.

It should be noted that this embodiment is described with reference to a multilayer optical disc having two data recording layers such that both layers are read by a laser beam incident to the same side of the disc. The invention shall not be limited to discs having two data recording layers, however, and may have more than two recording layers.

It is also not necessary for all data recording layers to be recordable, and the invention also applies to multiple layer optical discs that have at least one recordable data recording layer with the other layers being read-only.

This embodiment of the invention disposes dummy grooves to suppress local variations in the playback signal, but the invention shall not be so limited. Dummy pits, for example, could be used in place of dummy grooves insofar as the size of the mirror area is reduced and the pits are small enough that any crosstalk component is ignored.

It will also be noted that the dummy grooves are disposed near the address block in all address areas, but can be otherwise configured insofar as they reduce local fluctuations in the playback signal.

Furthermore, a multilayer optical disc according to the present invention has dummy grooves or pits near the address blocks of the address areas, but data can also be encoded using these grooves or pits. For example, to the extent that they do not adversely affect crosstalk, dummy grooves could be provided in the land tracks and dummy pits disposed to the groove tracks so that the land tracks and groove tracks can be distinguished.

The first and second layers could also be identified by, for example, using dummy grooves in the first layer and dummy pits in the second layer.

This embodiment of the invention has been described using a signal recorded to the second recording layer, but it will be obvious that local fluctuations in the playback signal can be reduced when reproducing signals recorded to the first recording layer by similarly providing dummy grooves near the address blocks in the address areas of the second recording layer. In this case a small light spot will be focused on the surface of the first recording film, and the larger light spot will be incident to the surface of the second recording layer.

The address areas in this embodiment of the invention comprise two address blocks of multiple pits, but other configurations are also possible if the address pits have a pit and land shape.

The dummy grooves and address blocks in the present embodiment are also formed in the center of the tracks, but as shown in Fig. 13 the address blocks and dummy grooves could be formed at the boundary between the land tracks and groove tracks.

Yet further, the address areas are disposed aligned in the radial direction of the disc in this embodiment of the invention. It is also possible, however, to reduce the difference in reflectivity between where a track is present and where a track is not present, and thereby reduce local fluctuations in the playback signal, by providing dummy grooves even when the address areas are irregularly aligned.

Dummy grooves in the present embodiment are disposed offset in the radial direction half the track width from the track center, but can be disposed at any other location where local fluctuations in the playback signal can be reduced.

A multilayer optical disc according to this embodiment of the invention has dummy grooves or pits disposed near the address blocks of the address areas, but

the address areas can alternatively be dispersely located so that there are no local fluctuations due to reflections from address areas in layers other than the playback layer. If the address areas are dispersely located, variation in laser beam diffraction efficiency is reduced while still achieving the benefits of the present embodiment.

Randomly locating the address areas as shown in Fig. 16 is the preferred method of dispersely locating the address areas. If the address areas are located at a specific storage capacity increment in the data area, however, the address areas can be arranged in a spiral pattern as shown in Fig. 17 by offsetting the address areas a substantially constant disc center angle q (angle to the disc center). In this case the address areas are not aligned in the radial direction over a period of several ten tracks. In other words, the arrangement of the address areas in the tangential direction does not match the arrangement in the radial direction.

The disc shown in Fig. 17 can be a constant angular velocity (CAV) type disc, or a constant linear velocity (CLV) type disc. The spirals also turn in the same direction in the first and second layers in the example shown in Fig. 17, but the spirals could turn in opposite directions. The disc could also be radially segmented into a number of zones (such as an inside zone, middle zone, and

outside zone) and the address areas 1801, 1803 offset in adjacent zones. The discs shown in Fig. 18 could also be a constant angular velocity (CAV) type disc or a constant linear velocity (CLV) type disc. In the example shown in Fig. 18, the distance in the track direction between adjacent address areas is constant. The tangent to the curve of the arc-shaped address areas 1801, 1803 in each zone is offset from the radial direction of the disc. Groups of address areas thus disposed at an angle or slope to the radial direction of the disc are referred to below as "sloped address area groups."

Fig. 19 shows the address areas in Fig. 17 enlarged (note that the direction of rotation of the spirals defined by the address areas is opposite in Fig. 17 and Fig. 19). The address areas can also be arranged so that the address areas do not overlap in the first and second layers.

The address areas can also be arranged in other ways insofar as the resulting address area groups do not produce local variations that prevent tracking the slice level in playback signals from other layers. The dummy grooves or pits can also be formed or not formed.

Fig. 20 and Fig. 21 show a light spot 1901 incident to the first layer when reproducing data from the second layer. Fig. 20 (a) corresponds to an optical disc as shown in Fig. 18. Fig. 20 (a) shows that the sloped address

area group 1902 in one zone is completely contained within light spot 1901, and Fig. 20 (b) shows that perpendicular address area group 1903 having no slope (that is, a group of address areas aligned in the radial direction) is also completely contained within the light spot 1901. Fig. 21 (a) corresponds to the optical disc shown in Fig. 17. In this case sloped address area group 1905 diagonally traverses the light spot 1901, and perpendicular address area group 1906 likewise perpendicularly traverses the light spot 1901.

Correct signal reproduction is not possible if reflections from the mirror parts of the address area are superimposed on the playback signal from the second layer as a result of the address area being completely contained within the light spot 1901 and the slice level of the playback system cannot track local fluctuations in the playback signal due to such superimposition.

The sloped address area group 1902 shown in Fig. 20 (a) and the perpendicular address area group 1903 shown in Fig. 20 (b) are compared next below. Both sloped address area group 1902 and perpendicular address area group 1903 have the same width W. When the address area group is completely contained within the light spot as shown in the figures, the area of the light spot occupied by the address area group is substantially the same in both cases as shown in Fig. 20 (a) and Fig. 20 (b). However, as

the light spot 1901 moves with the passage of time Dt in the track direction, that is, right or left as seen in the figure, to the position indicated by light spot 1901-a in Fig. 20 (a) or Fig. 20 (b), part Ds of the sloped address area group 1902 moves outside the light spot 1901-a. The perpendicular address area group 1903, however, remains completely within the light spot 1901-a. The sloped address area group 1902 thus occupies a smaller area in light spot 1901-a than does the perpendicular address area group 1903.

When the light spot moves further over time Dt to the location indicated by light spot 1901-b, a larger part (approximately 2Ds) of the sloped address area group 1902 is outside the light spot 1901-b, and approximately half (approximately 2Ds) of the perpendicular address area group 1903 is outside the light spot 1901-b.

If the change Ds in the area of the light spot 1901 occupied by the address area over time Dt is fluctuation F, fluctuation F can be denoted as:

$$F = Ds/Dt.$$

Referring to the above example, fluctuation Fs is $\Delta s/\Delta t$ in the case of sloped address area group 1902, but fluctuation Fv for perpendicular address area group 1903 is $2\Delta s/\Delta t$ or approximately twice Fs. Fluctuation Fs for sloped address area group 1902 depends upon the angle of the

slope and the width W of the area, but is constantly smaller than fluctuation Fv for the perpendicular address area group 1903. Fluctuation F is further proportional to the slope in areas 411 and 412 of envelope signal 49 in Fig. 4. Because this slope is preferably low as described above, sloped address area group 1902 is preferable to perpendicular address area group 1903.

It is therefore possible to achieve better playback performance by disposing the address areas extending in the radial direction at an angle to the direction of light spot travel than by placing the address areas perpendicular to the direction of light spot travel.

An sloped address area group 1905 and perpendicular address area group 1906 that completely traverse the light spot are compared next with reference to Fig. 21 (a) and Fig. 21 (b). The apparent width We as measured in line with the slope is narrower than the width W of the sloped address area group 1905. Because the apparent width We of the sloped address area group 1905 is narrower than the width W of the perpendicular address area group 1906, fluctuation Fs with sloped address area group 1905 is less than fluctuation Fv with perpendicular address area group 1906. It is therefore also possible in the cases shown in Fig. 21 (a) and Fig. 21 (b) to achieve better playback performance by disposing the address

areas extending in the radial direction at an angle to the direction of light spot travel than by placing the address areas perpendicular to the direction of light spot travel.

Playback performance when there is leakage from the first layer when reading from the second layer, for example, depends on numerous factors, including the location of the address areas, spot diameter, reflectivity of the second layer, reflectivity of the first layer, transmittance of first layer, and the slice level response rate. It follows that it also possible to provide some latitude in recording film design and the design of the playback system by arranging the address areas as described above.

It will be obvious to one with ordinary skill in the related art that the above also applies to the arrangement of address areas in the second layer when reproducing the first layer, and better playback performance can be achieved by placing the address areas oriented in the radial direction at an angle to the direction of light spot travel when compared with address areas disposed perpendicularly to the direction of light spot travel.

It is also possible to prevent a drop in the playback performance of a particular playback layer by disposing the address areas in layers that are not played back so that they are not perpendicular to the direction of light spot travel.

It will be noted that the address areas can be disposed across multiple tracks perpendicularly to the direction of light spot travel if the width of the multiple tracks is ignorably small, such as approximately 10% or less, relative to the spot diameter.

A multilayer optical disc according to this embodiment of the invention is described above with reference to address areas containing pit and land sequences, but will be noted to have the same effect when applied to other areas containing pit and land sequences by reducing, such as a servo area, as a result of the dummy grooves or pits and lands reducing the size of mirror areas near address blocks.

Embodiment 2

A multilayer optical disc according to another embodiment of the present invention is described next below with reference to the accompanying figures. Fig. 5 is a section view of a multilayer optical disc according to this second embodiment of the invention. As shown in Fig. 5, this two-layer optical disc has transparent substrates 501 and 502 typically made of polycarbonate resin, a first recording film 503, semitransparent reflective film 504 for passing or reflecting a laser beam incident from substrate 501; second recording film 505; reflective film 506 for

reflecting a laser beam incident from substrate 501; and adhesive 507 with the ability to pass light used to bond substrate 501 and substrate 502.

Fig. 6 shows the sector structure of the two-layer optical disc shown in Fig. 5. As shown in Fig. 6, this two-layer optical disc 61 has a trench-like groove track 63 and a land track 62 disposed between adjacent groove tracks 23. Data areas 65 are provided in the groove tracks, and address areas 64 are provided in the land tracks.

When one revolution of each track is divided into plural sectors, an address area 64 and data area 65 is provided for each sector. In this case each address area 64 is also referred to as a "sector address area" [address area, sic].

Fig. 7 shows the address area 64 of the two-layer optical disc 61 in detail. An address area indicating the address of a particular sector of groove track a, 63b, 63c is provided in the adjacent land track 62a, 62b, 62c. To record the sector address of groove track 63a, for example, three address blocks 72, 73, 74 each containing plural pit sequences are provided in the address area of land track 62a. To indicate the sector address of groove track 63b, three address blocks 75, 76, 77 each containing plural pit sequences are similarly provided in the address area of land track 62b. Note also the dummy grooves 711, 712, 713,

714, 715, 716.

Fig. 8 shows recording marks 81 recorded to the second recording layer, light spots 82, 83, 84 for reproducing data from the second recording layer, and light spots 85, 86, 87 incident to the first recording layer when reproducing signals recorded to the second recording layer. Light spots 82 and 85, 83 and 86, and 84 and 87 are temporally coincident pairs of light spots emitted to the first and second layers. The diameter of the laser beam incident to each layer is approximately 1 μm on the second layer and approximately 60 μm on the first layer if the wavelength of the laser is 650 nm, the NA of the objective lens is 0.6, and the distance between layers is 40 μm.

Also shown in Fig. 8 are playback signal envelopes 88, 89, 810 where envelope 88 is the envelope of the playback signal of a signal recorded to a single-layer optical disc having recording characteristics equivalent to those of the second layer of the two-layer disc. Envelope 89 is the playback signal envelope when a signal recorded to the second recording layer of a conventional two-layer optical disc, that is, a two-layer optical disc that does not have dummy grooves, is reproduced. That envelope 89 has a local deviation not present in envelope 88 will be apparent. This is because when light spot 83 is emitted to read the second recording layer, an address area occupies

part of the area illuminated by the corresponding light spot 86 incident to the first layer in the area of light spot 83, reflection from the first layer decreases, a dc component caused by illumination outside the address area of the first layer is superimposed on the playback signal, and the playback signal from the second layer is apparently degraded. The playback signals cannot be correctly digitized in areas 811 and 812 of envelope 89.

Envelope 810, on the other hand, is the envelope for a playback signal reproduced from a signal recorded to the second recording layer of a two-layer optical disc having dummy grooves according to the present invention. Because of the dummy grooves adjacent to the address area in the first layer, the time constant of the drop in reflection increases. Because of the increased time constant, local variations in reflection are buffered even if the drop in reflection is approximately the same, thus providing more time to correctly digitize the playback signal and thereby enabling the recorded data to be correctly reproduced.

It should be noted that this embodiment is described with reference to a multilayer optical disc having two data recording layers such that both layers are read by a laser beam incident to the same side of the disc. The invention shall not be limited to discs having two data

recording layers, however, and may have more than two recording layers.

It is also not necessary for all data recording layers to be recordable, and the invention also applies to multiple layer optical discs that have at least one recordable data recording layer with the other layers being read-only.

This embodiment of the invention disposes dummy grooves to buffer local variations in the playback signal, but the invention shall not be so limited. Dummy pits, for example, could be used in place of dummy grooves insofar as the same effect is achieved.

It will also be noted that the dummy grooves are disposed near the address block in all address areas, but can be otherwise configured insofar as they reduce local fluctuations in the playback signal.

Furthermore, a multilayer optical disc according to the present invention has dummy grooves or pits near the address blocks of the address areas, but data can also be encoded using these grooves or pits. For example, dummy grooves could be provided in the first layer and dummy pits in the second layer so that the first and second layers can be distinguished.

This embodiment of the invention has been described using a signal recorded to the second recording

layer, but it will be obvious that local fluctuations in the playback signal can be buffered when reproducing signals recorded to the first recording layer by similarly providing dummy grooves near the address blocks in the address areas of the second recording layer.

The address areas in this embodiment of the invention comprise three address blocks each containing multiple pits, but other configurations are also possible if the address pits have a pit and land shape.

It will also be noted that the address areas are disposed aligned in the radial direction of the disc in this embodiment of the invention. It is also possible, however, to alleviate variations in reflectivity between where address pits are present and where address pits are not present, and thereby buffer local fluctuations in the playback signal, by providing dummy grooves even when the address areas are irregularly aligned.

The dummy grooves in this embodiment are provided at the same position in the radial direction relative to the address blocks, but can be otherwise disposed insofar as the dummy grooves still buffer local fluctuations in the playback signal.

The dummy grooves in this embodiment are rectangular, but can be wedge shaped as shown in Fig. 14 with the groove width increasing in proximity to the address

block. By forming grooves that narrow with distance from the address block, local fluctuations in the playback signal can be further buffered.

The dummy grooves shown in Fig. 7 are also approximately the same length as the address area, but shall not be so limited. As shown in Fig. 15, for example, the dummy grooves can be formed continuously between consecutive address areas. The effect of dc components introduced from other layers can thus be made the same in all data areas.

A multilayer optical disc according to this embodiment of the invention is described above with reference to address areas comprising pit and land sequences, but will be noted to have the same effect when applied to other areas containing pit and land sequences, such as a servo area, where the presence dummy grooves or pits reduces the size of mirror areas near address blocks.

By providing dummy grooves or a pit and land sequence in an area adjacent in the radial direction to address areas containing pit and land address pits in a multilayer optical disc having plural data recording layers of which at least one is optically recordable and which all are read by a light beam incident to the same side thereof as described above, local fluctuations in the playback signal from a particular data playback layer due to

interference from the address area of a layer other than the playback layer can be reduced. Data can therefore be correctly reproduced.

Furthermore, by providing dummy grooves or a pit and land sequence in an area adjacent in the circumferential direction to address areas containing pit and land address pits in a multilayer optical disc having plural data recording layers of which at least one is optically recordable and which all are read by a light beam incident to the same side thereof as described above, local fluctuations in the playback signal from a particular data playback layer due to interference from the address area of a layer other than the playback layer can be buffered. Data can therefore be correctly reproduced.

A multilayer optical disc for buffering sharp changes in light reflected from the disc by preforming dummy grooves or pit and land sequences in the surface of the disc is described in the preceding embodiments. The embodiment described next below is a recording method and apparatus for recording reflection-preventing marks to a locally unrecorded area of the disc so as to buffer sharp changes in light reflected from said area when this area of the disc is unrecorded due, for example, to a scratch on the disc surface.

Embodiment 3

Optical discs typically have a sector structure and data is recorded by sector. Recording data therefore does not stop in the middle of a sector unless a problem such as a tracking servo error or focusing servo error occurs during recording. Note, further, that plural sectors are grouped in blocks and data is recorded in blocks with error correction codes added to the data blocks in order to improve reliability during data reproduction.

Although adding error correction codes improves reliability during data reproduction, there will still be times when data cannot be recorded or reproduced due, for example, to manufacturing defects, scratches from normal use, and deterioration of the recording film as a result of repeated recording. These problems are addressed as follows.

One method is to actually record data and immediately reproduce the data to check whether it was correctly recorded. If the data is not correctly recorded, recording is attempted at a different disc location.

Another method tests address detection. That is, if the address assigned to a particular sector cannot be detected, or if the address data is redundantly recorded three or four times and two or more address blocks cannot be detected, or if some other address detection standard

cannot be cleared, then the corresponding sector is determined lacking in reliability. Recording to that sector, or to the entire block containing that sector, is then prohibited and the data is recorded to a reserved disc area.

The following problems are present when recording and reproducing data using an optical disc having plural recording layers.

A phase-change material, organic dye layer, or other material is normally used for the recording layer. Data is recorded by emitting a laser beam to form pits with changed optical characteristics in the surface of the recording layer medium. Therefore, when recording to a deeper recording layer as seen from the laser beam incidence side, the power of the laser beam reaching the deeper recording layer varies as a result of differences in the optical characteristics of the recorded and unrecorded parts of the recording layers in front of (that is, shallower than) the layer being recorded. Such fluctuations in beam power adversely affect reading and writing performance.

This is further described using a two-layer optical disc by way of example. Fig. 26 is used to describe the power of a laser beam reaching the second recording layer when there are recorded and unrecorded areas in the first recording layer. Shown in Fig. 26 are first recording layer 2202, second recording layer 2204, unrecorded area 2601

in the first recording layer, recorded area 2602 in the first recording layer, and laser beams 2603, 2604, 2605.

The first recording layer 2202 and second recording layer 2204 are a phase-change material. The first recording layer 2202 has optical characteristics as shown in Fig. 28. When unrecorded, the recording layer is crystalline phase as indicated on the left side of Fig. 28. When exposed to a laser beam, the crystalline phase turns amorphous as shown on the right side in Fig. 28, forming a pit. In the unrecorded crystalline phase, 20% of incident light is reflected, 40% is absorbed, and 40% is passed to the next layer. When recorded and amorphous as shown in the right, 10% of incident light is reflected, 30% is absorbed, and 60% is passed.

If laser beams 2603, 2604, 2605 are emitted with the same power, the power of the laser beams reaching the second recording layer ranked from strongest to weakest will be 2603, 2604, 2605. This is because the optical characteristics, specifically the transmittance, of the first recording layer are different when the recording layer is crystalline and when it is amorphous. Because transmittance is higher when the recording layer is amorphous than when crystalline, the light beam passes more easily as the total area of the pits increases inside the light spot formed by the light beam incident to the first

recording layer. In other words, the power of the laser beam reaching the second recording layer is greatest when laser beam 2603 is emitted, that is, when the total area of pits in the light spot of the laser beam incident to the first recording layer is greatest. The problem here is that such variations in beam power cause deviations in the shape of the formed pits and distortion in the playback signal.

One way to solve this problem is to first record the recording layer closest to the side to which the laser beam is emitted. Uniform transmittance can thus be maintained throughout the first recording layer, and constant beam power can thus be achieved when recording to the next, deeper, recording layer.

However, if the problem is addressed by simply recording data to the first recording layer first, unrecorded areas could be left in the first recording layer when, for example, data is recorded to a reserved disc area instead of to the addressed sector or sector block as a result of failing the above-described address detection test. The problem with this conventional recording method, therefore, is that the transmittance of the recording layer near the disc surface changes and the effective power of the laser beam for recording to a deeper recording layer changes when there are unrecorded areas in the surface-side layer because address detection is not possible due, for example,

to scratches or fingerprints on the surface layer.

An object of the present embodiment is therefore to provide an optical data recording method and apparatus that is not affected by changes in the optical characteristics resulting from recording or not recording to another layer.

The optical data recording method of this embodiment is a method for recording data to an optical disc having plural data recording layers of which at least one is optically recordable and which all are read by a light beam incident to the same side thereof, and recording dummy data to an area determined to be unrecordable while recording data.

An area is determined unrecordable in this optical data recording method of the invention when specific address reading conditions are not met.

A further optical data recording method of the invention is a method for recording data to an optical disc having plural data recording layers of which at least one is optically recordable and which all are read by a light beam incident to the same side thereof, and recording dummy data to a specific area other than the area for recording data.

In this optical data recording method the data recording layers are segmented in the radial direction into plural zones, and the above-noted specific areas are areas

bordering an adjacent zone.

Further preferably, these specific areas are areas where disc management information is recorded.

Fig. 22 shows the configuration of an optical disc according to this embodiment of the invention. Shown in Fig. 22 are first substrate 2201, first recording layer 2202, adhesive resin 2203, second recording layer 2204, second substrate 2205, clamping hole 2206, lead-in area 2207, defect list area 2208, spare area 2209, and data area 2210. The first substrate 2201 and second substrate 2205 are a polycarbonate resin and protect the first recording layer 2202 and second recording layer 2204. Also shown are lead-in area 2211, defect list area 2212, spare area 2213, and data area 2214.

First recording layer 2202 and second recording layer 2204 have plural spiral or concentric tracks. Each track has multiple sectors. Note that in this embodiment of the invention first recording layer 2202 is recorded first and second recording layer 2204 is recorded after the first recording layer 2202 is completely recorded. Recording to second recording layer 2204 can commence after first confirming that all of first recording layer 2202 has been recorded. If the data area 2210, 2214 is divided into zones as shown in Fig. 23, it is alternatively possible to confirm that recording a specific zone of the first recording layer

2202 is completed, and then record to the corresponding zone at the same radial position in the second recording layer 2204.

The address is also assumed in this embodiment to be redundantly recorded with pits and lands by writing the address data four times for each sector. Thus redundantly recording the address data increases the address read rate particularly during playback. It will be obvious that redundantly writing the address data shall not be limited to recording each address four times. Recording the address data shall also not be limited to each sector. Address data can also be recorded using wobble data or other method not dependent on pits and lands.

Data is modulated according to a specific modulation rule, such as 1-7 modulation, and recorded to each sector as sequences of pits. The pits are formed by modulating laser beam power to change the optical characteristics of the recording layer material. The laser beam is emitted from the first substrate 2201 side of the disc. The second recording layer 2204 is read and recorded by a laser beam passing through the first recording layer. The first recording layer 2202 in this embodiment is a phase-change material with optical characteristics as shown in Fig. 28. The recording layer shall not be limited to phase-change materials and could be an organic dye film,

for example. The optical characteristics in Fig. 28 are shown by way of example only and may differ therefrom. The adhesive resin 2203 bonds the first recording layer 2202 and second recording layer 2204 together. The clamping hole 2206 is used to mount the disc on the spindle of a spindle motor for rotationally driving the disc.

Fig. 23 is a block diagram of an optical data recording apparatus according to a preferred embodiment of the invention. Shown in Fig. 23 are the optical disc drive 200, optical disc 201, spindle motor 202, optical head 203, laser beam controller 204, servo circuit 205, playback signal digitizer 206, digital signal processor 207, recording compensation circuit 208, CPU 209, and host PC 210.

The optical disc drive 200 comprises optical disc 201, spindle motor 202, optical head 203, laser beam controller 204, servo circuit 205, playback signal digitizer 206, digital signal processor 207, recording compensation circuit 208, and CPU 209.

The optical disc 201 is configured as shown in Fig. 22. The spindle motor 202 is a motor for rotationally driving the optical disc 201. The optical head 203 emits a laser beam to the optical disc 201, and converts the laser beam reflected from the optical disc 201 to an electrical signal output as the playback signal.

The laser beam controller 204 controls the power

of the laser beam output from optical head 203 based on commands from the CPU 209. The servo circuit 205 controls positioning the optical head 203, focusing, tracking, and rotational operation of the spindle motor 202. The playback signal digitizer 206 amplifies and samples the playback signal from the optical head 203 to generate a digital signal. The playback signal digitizer 206 also generates a clock signal synchronized to this digital signal using an internal PLL (not shown in the figure).

When reading addresses, the digital signal processor 207 applies a specific demodulation process and address data extraction process to the digital signal for the address area. When reading data, the digital signal processor 207 applies a specific demodulation process and error correction process to extract the playback data. During recording, the digital signal processor 207 adds an error correction code to the recording data and applies a specific modulation process to generate the modulated recording data. The digital signal processor 207 also generates the dummy data of the present invention as further described below.

The recording compensation circuit 208 converts the modulated recording data to a pulse train of laser modulation data, and then adjusts the pulse width, amplitude, and other characteristics of the laser modulation

data to generate a record pulse signal for desirably forming pits.

The CPU 209 provides overall control of the optical disc drive. The host PC 210 comprises a computer (not shown in the figure), software application (not shown in the figure), and operating system (not shown in the figure), and issues read and write requests to the optical disc drive 200.

Fig. 24 shows whether something is recorded to various blocks in the data area 2210, spare area 2209, and defect list area 2208. Shaded blocks in Fig. 24 contain some type of recorded data, and white spaces indicate unrecorded blocks. Operation of the above-described optical disc drive during recording is described next with reference to Fig. 24.

When the host PC 210 sends a data write (record) request to the CPU 209 to write data to the first recording layer (specifically to record from block B01 to B05 in the data area 2210), the servo circuit 205 moves the optical head 203 near the sector addressed for the write request. The digital signal processor 207 then runs the read-address process using the digital signal obtained from the optical head 203 and playback signal digitizer 206. When the head reaches the first sector in block B01, the address is read again. If the address detection test is

passed, a laser beam modulated by the digital signal processor 207, recording compensation circuit 208, laser beam controller 204, and optical head 203 is emitted, and data is recorded in sequence from block B01 as shown in Fig. 24 (a). The laser beam output from the optical head at this time is controlled by the laser beam controller 204 to the specific power level indicated by the CPU 209. The address detection test is passed in this embodiment if the address is successfully read two or more times when the same address data is recorded four times to the address block.

What happens when the address detection test is not passed in sector B07 while recording block B03 is described next. The digital signal processor 207 adds an error correction code to blocks of plural sectors. If even one sector that fails the address detection test is found within a block being recorded, it interrupts recording, moves the optical head 203 to the spare area 2209, and applies the read-address process to the address indicated by CPU 209 (the address of the first sector in block B09 in this example). If the address detection test is passed, the block of data for which recording was interrupted is recorded to block B09 as shown in Fig. 24 (c). It is assumed here that data was previously recorded to block B08.

When recording data to the spare area 2209 ends, the optical head 203 moves back to the data area 2210 and records the remaining data to the blocks B04 and B05 following the block B03 that failed the address detection test as shown in Fig. 24 (d).

When data recording ends, optical head 203 moves to the defect list area 2208 and records the start address of the defective block, and the start address of the block in the spare area 2209 where the data was re-recorded, to block B14 as instructed by CPU 209. See Fig. 24 (e).

When recording to the defect list area 2208 ends, optical head 203 returns to the data area 2210 and records dummy data to the defective block B03 as shown in Fig. 24 (f). Note that the read-address process is also used to record the dummy data but a more lenient standard can be used for the address detection test than when recording real data. For example, a passing standard could be successfully reading one of four redundant addresses in the write sector, passing the address detection test in the immediately preceding sector, or other standard insofar as it also assures that dummy data will not be mistakenly written to a different sector. A monotone signal starting with a VFO signal, for example, is recorded as the dummy data.

Variations in the transmittance of a recorded layer can thus be eliminated and uniform beam power can be assured when recording to a different layer by recording dummy data to sectors in the recorded layer where real data cannot be recorded because the address could not be normally detected during recording.

The defective sector processing algorithm in the above embodiment is also described by way of example only. Other algorithms, such as recording dummy data and then recording the defective block address data to the defect list area 2208, can be used insofar dummy data is recorded to any sector that did not pass the address detection test. The location of the spare area 2209 shall also not be limited to the inside circumference area of the disc as in this embodiment.

This embodiment of the invention records dummy data to the block containing a sector that failed the address detection test during data recording, but the invention shall not be so limited. More specifically, dummy data can be recorded to any block containing a sector left unrecorded as a result of a focusing servo error or tracking servo error, for example, preventing normal data recording to a sector.

Furthermore, while dummy data is recorded in block units in the present embodiment, it is alternatively possible to record dummy data only to those sectors left

unrecorded.

The present embodiment also records the dummy data within the user data recording process, but dummy data can also be recorded during the disc initialization process when the disc is formatted and certified. In this case data used for certification can be used for the dummy data. When sectors that fail the address detection test are detected during the certification process, dummy data can be recorded by sector unit rather than by block unit as happens during the data recording operation described above.

Further preferably, dummy data is recorded using a weaker laser beam than is used during normal data recording in order to prevent accidentally erasing data in an adjacent track.

Dummy data can also be pre-recorded to the defect list area 2208 and spare area 2209 the first time user data is recorded or during optical disc 201 formatting. By thus pre-recording dummy data to the defect list area 2208 and spare area 2209, the power of the laser beam reaching the second recording layer at the same radial position as the defect list area 2208 and spare area 2209 can be kept constant when recording to the second recording layer.

When the data area 2210 is segmented into plural

zones as shown in Fig. 25 the disc speed is different with ZCLV recording and the number of sectors per track is different in each zone. If several tracks at the zone boundary are unrecorded, dummy data can be recorded during disc formatting or the first time user data is recorded. This avoids situations such as shown in Fig. 27 (b), and keeps the power of the laser beam incident to the second recording layer located at the same radial position constant when recording to the second recording layer. Fig. 27 (a) shows the first recording layer completely recorded, Fig. 27 (b) shows the first recording layer partially recorded, and Fig. 27 (c) shows the first recording layer completely blank (unrecorded). The power of the laser beam reaching the second recording layer in each of the cases shown in Figs. 27 (a), (b), and (c) is indicated by the waveform below each figure. The dotted line waveforms show the waveform from Fig. 27 (a) for comparison.

The invention shall not be limited to recording dummy data to the spare area, defect list area, or zone boundary areas described above. More specifically, by recording dummy data to a specific area outside the user data recording area, the power of the laser beam reaching the second recording layer located at the same radial position as the dummy data recording area can be held constant when recording to the second recording layer.

Although the present invention has been described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications will be apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims, unless they depart therefrom.